Europäisches Patentamt
European Patent Office
Office européen des brevets

Publication number: **0 284 891**
A1

EUROPEAN PATENT APPLICATION

Application number: 88104143.8

Int. Cl.4: B01J 35/04, F01N 3/10, B01D 53/36

Date of filing: 16.03.88

Priority: 23.03.87 US 28749

Date of publication of application: 05.10.88 Bulletin 88/40

Designated Contracting States: AT BE CH DE ES FR GB IT LI NL SE

Applicant: W.R. GRACE & CO.
Grace Plaza 1114 Avenue of the Americas
New York New York 10036(US)

Inventor: Whittenberger, William A.
10749 Route 700
Garretsville Ohio 44231(US)

Representative: UEXKÜLL & STOLBERG
Patentanwälte
Beselerstrasse 4
D-2000 Hamburg 52(DE)

Optimized stacking of metal foil in catalytic converters.

There is provided a method for optimizing the stacking characteristics of a thin metal foil corrugated in a chevron pattern and folded in an accordion fashion or zig-zag manner to form a stack useful as a catalyst support member for catalytic converters for treating exhaust gases from internal combustion engines. This method provides a more stable and stronger stack.

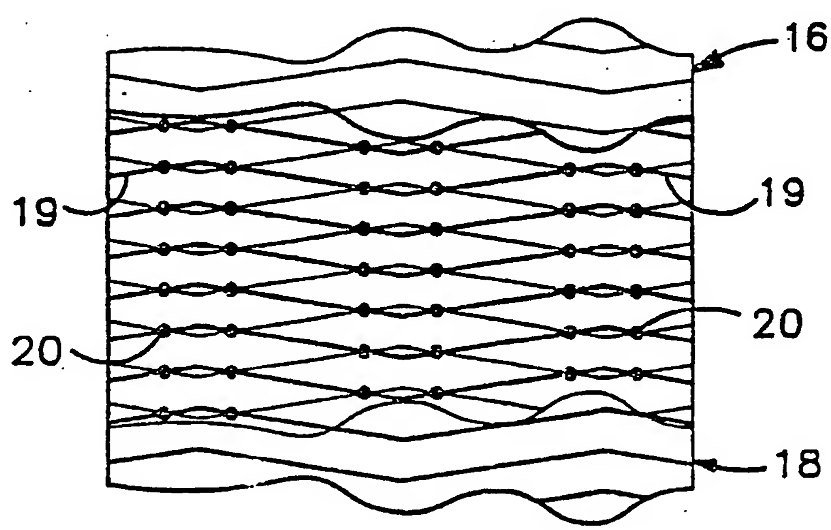


FIG. 2

EP 0 284 891 A1

METHOD FOR OPTIMIZING STACKING CHARACTERISTICS OF CORRUGATED METAL FOIL

This invention relates, as indicated, to a method for optimizing the stacking characteristics of metal foil corrugated in a chevron pattern and folded in an accordion fashion or zig-zag manner to form a stack. Stacks of this type are used as catalyst support elements in catalytic converters which are primarily useful in removing pollutants from exhaust from internal combustion engines of either the spark ignited or the compression ignited types. Optimal stacking characteristics are desirable because they lead to the production of a more stable and stronger stack.

BACKGROUND OF THE INVENTION

Recently there have been several developments in the field of metal foil supported catalytic media. An early development in metallic carriers for catalysts is desirabed in U. S. Patent 1,636,685 dated 26 July 1927 to Downs. Here metallic (iron) particles are treated by dipping into melted aluminum. An alloying action takes place between the aluminum and iron. The resulting surface is very satisfactory for the deposition of catalytic materials such as a metal of Group V or Group VI of the Periodic Table. Such structures are adapted for vapor phase catalytic oxidation of organic compounds.

Patent 2,658,742 dated 10 November 1953 to Suter et al discloses a metallic catalyst support for removing harmful ingredients from exhaust streams. Platinum and palladium are disclosed as useful to aid in oxidation of combustible materials, e.g., carbon monoxide. Stainless steel is disclosed as a base metal for the catalyst.

Bernstein et al U. S. Patent 3,773,894 disclose a metallic catalyst supported on a metallic substrate as a catalytic converter for internal combustion engine exhaust gases. Various physical forms of the catalyst support are shown including spiral wound screen and cordierite honeycomb.

The patent to Retallick 4,301,039 dated 17 November 1981 discloses a method of making a metallic catalyst support in a spirally wound form whereby indentations in the surface of the metal foil will not nest together.

U. S. Patent 4,318,888 dated 9 March 1982 to Chapman et al discloses a spirally wound foil structure having a corrugated surface and distinct different catalysts supported on confronting surfaces.

U. S. Patent 4,402,871 to Retallick dated 6 September 1983 discloses a honeycomb catalyst support formed by folding a single layer of metal foil back and forth upon itself in an accordion or zig-zag fashion. Each layer in the honeycomb has indentations of uniform height so that the spacing between layers is equal to this height. A different pattern of indentations is used on alternate layers and the indentations are on opposite sides of the strip in alternate layers. This structure prevents nesting of confronting layers.

More recent structures are made of a thin ferritic stainless steel of the type referred to by Kilbane in patent application serial no. 741,282 filed 4 June 1985, and by Retallick in application no. 738,485 filed 28 May 1985, corrugated and fan folded or folded back and forth upon itself. The surface of the strip is provided with a catalytically active agent for decontaminating an exhaust gas, e.g., the exhaust gas generated by an internal combustion engine. Reference may also be had to Cornelison patent application serial no. 796,710 filed 12 November 1985, which discloses a catalytically active fan folded element of the type which can be produced by the process disclosed in the application of Cornelison and Retallick, serial no. 830,698 filed 18 February 1986.

Thus, it will be seen that the general type of catalyst support element to which the present invention relates is generally well known. It has now been found that there is a special relationship between the parameters defining the corrugated surface that when observed provides a stack of corrugated foil which is uniform and has no weak areas.

BRIEF STATEMENT OF THE INVENTION

Briefly stated, therefore, the present invention is in a method for optimizing the number of contact points, n, between confronting surfaces of an accordion folded metal foil corrugated in a chevron pattern which comprises dimensioning the pitch of the chevrons, p, and the angle of the chevron, alpha, and determining L, which is the length of each chevron from apex to apex, by the equation:

$$L = \frac{(n + 0.25)p}{2 \tan(\text{alpha})}, \text{ where } n = 1, 2, 3......$$

In the preferred cases, n is 3 or less.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention may be better understood by having reference to the annexed drawings wherein:

Figure 1 is a fragmentary plan drawing showing a section of the surface of a corrugated metal foil.

Figure 2 is a fragmentary plan drawing showing first and second layers in superimposed relation and showing the contact points between the peaks of the corrugations of the confronting surfaces.

DETAILED DESCRIPTION OF THE INVENTION

As above indicated, this invention concerns a method for optimizing the stacking characteristics of a metal foil corrugated in a chevron pattern. Optimal stacking characteristics lead to a more stable and therefore stronger stack of such foil when used in catalytic converters and similar applications, e.g., conducting catalyzed chemical reactions such as hydrogenation of an oil.

Figure 1 shows a typical corrugated foil 10. Lines 12 are peaks and spaces 14 represent valleys defining a corrugated surface such as is well known in the art. As shown in the drawing key parameters are identified as "p" which is the pitch or distance between peaks 12 in the indicated "length direction"; alpha is the chevron angle; 2L is the chevron pitch in a direction transversely of the metal strip 16.

Figure 2 is a fragmentary plan view with the first and second layers in superimposed relation, the first layer being depicted as visible through the second layer, and showing the contact points between the corrugations in confronting relation. Thus, there is shown the first corrugated strip 16 of Figure 1, having superimposed thereover on contacting relation therewith an overfolded portion 18 of the same corrugated strip 10 (Figure 1). When the strip portions 16 and 18 are in contacting relation, the peaks 12 of the strip portion 16 (Figure 1) intersect and contact the peaks 19 at the points 20 in a pattern as shown in Figure 2.

As one layer 16 or 18 is shifted longitudinally in the direction of length (Figure 1) relative to the other layer 18 or 16, as the case may be, through a distance equivalent to "p", the actual number of contact points 20 will vary. The statistical average number of points in contact per square inch is given by the equation:

$$\text{ave.pts./in}^2 = 2\tan(\text{alpha})/p^2$$

where "p" is in inches.

Depending upon the relationship among p, L and alpha, and how one layer 16 or 18 is shifted relative to the next layer, e.g., 18 or 16, the actual number of points in contact can be much more or much less than the average. The minimum possible number of points 20 in contact per square inch is given by the equation:

$$\text{min pts/in}^2 = \frac{\text{int}(2L\tan(\text{alpha})/p)}{Lp^2}$$

where int represents the operation that gives the largest integer less than or equal to the operand.

When L, p, and alpha are chosen such that the minimum number of contact points 20 is close to the average, then the stacking characteristics are optimized. Optimized accordion folded stacks are uniform and have no weak areas.

In practice, p is generally affected by performance characteristics other than stacking. In such case, one selects alpha to obtain a reasonable number of average contact points 20 per square inch, using the equation:

$$L = \frac{np}{2\tan(alpha)}, \text{ where } n = 1, 2, 3....$$

It is seen, therefore, that many values of L optimize the stacking characteristics. The minimum number of points 20 in contact can now be expressed by the equation:

$$\text{min pts/in2} = \frac{\text{int (n)}}{n} \times \frac{2\tan(alpha)}{p^2} = \frac{\text{int (n) x ave. pts./in}^2}{n}$$

When n is indeed an integer, the minimum number of points 20 in contact is equal to the average number of points 20 in contact, and stacking is optimized.

If L is selected to correspond to n=2, stacking is optimized as long as p and alpha are constant. If p becomes slightly larger or alpha slightly smaller, the minimum number of points 20 in contact is cut approximately in half. If p becomes slightly smaller or alpha slightly larger, no such drastic effect is observed. Therefore, when p or alpha are uncertain, L should be selected to be slightly larger than the calculated value so that catastrophic effects are eliminated, e.g., when the minimum contacts per in^2 are about one half the average number of contact points 20 per in^2.

It should be noted that the effect is not catastrophic when n is large. Unfortunately, considertions other than stacking usually dictate that L be small, which causes n to be in the preferred cases, 3 or less.

Accordingly, it has been found that the following equation, while it sacrifices some optimization, it eliminates catastrophic effects in most practical applications:

$$L = \frac{(n + 0.25)\,p}{2\tan(alpha)}, \; n = 1, 2, 3.....$$

The following Tables shows the conditions for optimal stacking, modified stacking and "catastrophic" effect.

TABLE I

OPTIMAL STACKING

MODEL FOR NEW CORRUGATOR
290-400 cells (nominal 320)

Foil thickness	0.0030	
Form gear clearance	0.0080	
	Gear with Clearance	Gear with Material
Normal diametral pitch	42	
Normal press, angle	20.0	
Helix angle alpha =	6.0	
Hob full depth	2.25/NDP	
Transverse diam. pitch	41.77	
Transverse press. angle	20.10	
Trans. p.a., radians	0.350835	
Cosine, trans. p.a.	0.939086	
Tangent, trans. p.a.	0.365975	
Circular pitch	0.075212	
Base pitch	0.070630	
No. of teeth	28	
Addendum factor	1.420/NDP	
Dedendum factor	0.830/NDP	
Addendum	0.033810	
Pitch diameter	0.670339	
Outside diameter	0.737958	
Base diameter	0.629506	
Hob offset	0.010000	
Blank diameter	0.7450	
Blank length	L= 0.7755	
Overlap factor	1.0001	
P.A. at blank dia. (rad)	0.564279	
Tooth thickness at P.D.	0.044925	
Tooth thickness at B.D.	0.051720	
Land thickness	0.010066	
Minimum pitch diameter	0.689429	0.684429
Equiv. pitch diameter	0.705280	0.705280
(Iteration check)	1.000007	

	CASE I	CASE II	CASE III	CASE I\
Corrugation height	0.045720	0.42000	0.038000	0.03000
Expected correg. length	0.79132	0.079550	0.079998	0.08089
Stretch factor	1.0300	1.0300	1.0300	1.0300
Actual corrug. length	P = 0.081506	0.081936	0.082398	0.08332
Height to length	0.560939	0.512595	0.461174	0.36004
Cells per sq. inch	268.4	290.6	319.4	400.1
Ave. contacts per in^2	31.6424	31.3112	30.9609	30.277
Min. contacts per in^2	31.6415	31.4755	31.2989	30.9517

TABLE 2

CATASTROPHIC EFFECT

MODEL FOR NEW CORRUGATOR
290-400 cells (nominal 320)

Foil thickness	0.0030	
Form gear clearance	0.0080	
	Gear with Clearance	Gear with Material
Normal diametral pitch	42	
Normal press, angle	20.0	
Helix angle	alpha = 6.0	
Hob full depth	2.25/NDP	
Transverse diam. pitch	41.77	
Transverse press. angle	20.10	
Trans. p.a., radians	0.350835	
Cosine, trans. p.a.	0.939086	
Tangent, trans. p.a.	0.365975	
Circular pitch	0.075212	
Base pitch	0.070630	
No. of teeth	28	
Addendum factor	1.420/NDP	
Dedendum factor	0.830/NDP	
Addendum	0.033810	
Pitch diameter	0.670339	
Outside diameter	0.737958	
Base diameter	0.629506	
Hob offset	0.010000	
Blank diameter	0.7450	
Blank length	L= 0.7750	
Overlap factor	1.0001	
P.A. at blank dia. (rad)	0.564279	
Tooth thickness at P.D.	0.044925	
Tooth thickness at B.D.	0.051720	
Land thickness	0.010066	
Minimum pitch diameter	0.689429	0.684429
Equiv. pitch diameter	0.705280	0.705280
(Iteration check)	1.000007	

	CASE V	CASE VI	CASE VII	CASE VII
Corrugation height	0.045720	0.42000	0.038000	0.030000
Expected corrug. length	0.79132	0.079550	0.079998	0.080896
Stretch factor	1.0300	1.0300	1.0300	1.0300
Actual correg. length	P = 0.081506	0.081936	0.082398	0.083323
Height to length	0.560939	0.512595	0.461174	0.360045
Cells per sq. inch	268.4	290.6	319.4	400.1
Ave. contacts per in^2	31.6424	31.3112	30.9609	30.2776
Min. contacts per in^2	15.8310	15.7479	15.6596	15.4858

TABLE 3

MODIFIED STACKING

MODEL FOR NEW CORRUGATOR
290-400 cells (nominal 320)

Foil thickness	0.0030	
Form gear clearance	0.0080	
	Gear with Clearance	Gear with Material
Normal diametral pitch	42	
Normal press, angle	20.0	
Helix angle alpha =	6.0	
Hob full depth	2.25/NDP	
Transverse diam. pitch	41.77	
Transverse press. angle	20.10	
Trans. p.a., radians	0.350835	
Cosine, trans. p.a.	0.939086	
Tangent, trans. p.a.	0.365975	
Circular pitch	0.075212	
Base pitch	0.070630	
No. of teeth	28	
Addendum factor	1.420/NDP	
Dedendum factor	0.830/NDP	
Addendum	0.033810	
Pitch diameter	0.670339	
Outside diameter	0.737958	
Base diameter	0.629506	
Hob offset	0.010000	
Blank diameter	0.7450	
Blank length	L= 0.8750	
Overlap factor	1.2567	
P.A. at blank dia. (rad)	0.564279	
Tooth thickness at P.D.	0.044925	
Tooth thickness at B.D.	0.051720	
Land thickness	0.010066	
Minimum pitch diameter	0.689429	0.684429
Equiv. pitch diameter	0.705280	0.705280
(Iteration check)	1.000007	

	CASE IX	CASE X	CASE XI	CASE XII
Corrugation height	0.045720	0.42000	0.038000	0.030000
Expected corrug. length	0.79132	0.079550	0.079998	0.080896
Stretch factor	1.0300	1.0300	1.0300	1.0300
Actual correg. length	P = 0.081506	0.081936	0.082398	0.083323
Height to length	0.560939	0.512595	0.461174	0.360045
Cells per sq. inch	268.4	290.6	319.4	400.1
Ave. contacts per in^2	31.6424	31.3112	30.9609	30.2776
Min. contacts per in^2	28.0434	27.8963	27.7398	27.4320

In the best mode of carrying out my invention, I have determined that for best results alpha is 6° to 7°, p is about 0.080" up to 0.125", L is 0.75" to about 2" and the thickness of the foil is 0.003". The conditions of Cases IX thru XII in the above Table III are the most satisfactory all things considered.

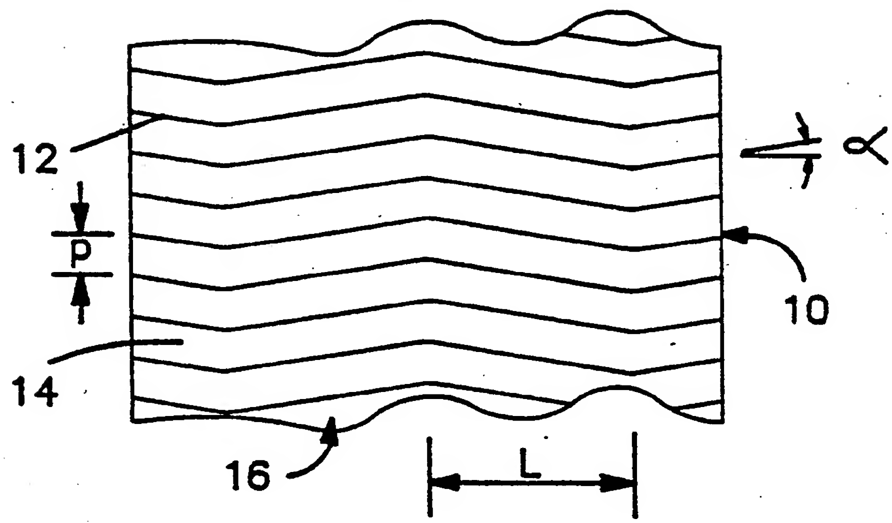
Claims

1. A method for optimizing the number of contact points, n, between confronting surfaces of accordion folded metal foil corrugated in a chevron pattern which comprises dimensioning the pitch of the chevrons, p, and the angle of the chevrons, alpha, and determining L, which is the length of each chevron from apex to apex, from the equation:

$$L = \frac{(n + 0.25)\,p}{2\tan(\text{alpha})}, \quad n = 1, 2, 3.....$$

2. A method as defined in Claim 1 wherein n is 3 or less.

FIG. 1



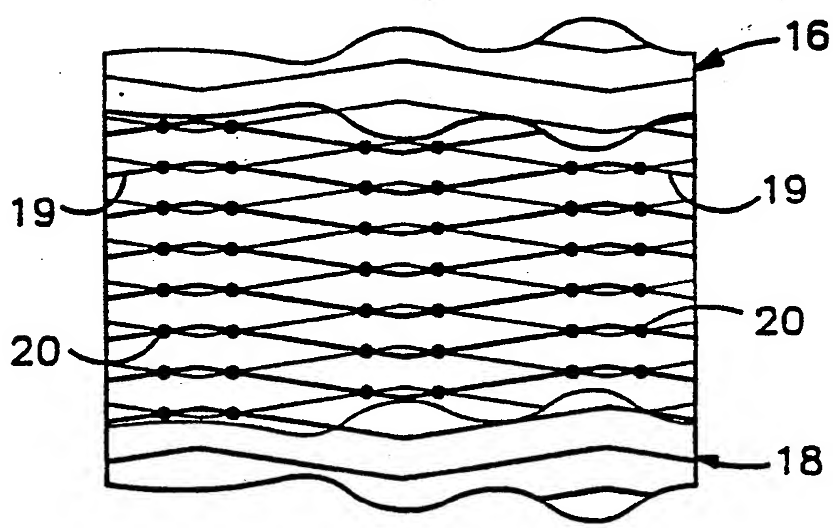


FIG. 2

European Patent Office

EUROPEAN SEARCH REPORT

Application Number

EP 88 10 4143

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.4)
P,D X	EP-A-0 222 355 (R.C. CORNELISON) * claims 1-4; page 5, lines 8-18; page 10, lines 17-20; figure 5 * ---	1,2	B 01 J 35/04 F 01 N 3/10 B 01 D 53/36
A	GB-A-2 094 658 (KERNFORSCHUNGSANLAGE JULICH GMBH) ---		
A	EP-A-0 151 229 (SÜDDEUTSCHE KÜHLERFABRIK JULIUS FR. BEHR GMBH & CO. KG) ---		
A	FR-A-2 250 569 (UNITED KINGDOM ATOMIC ENERGY AUTHORIY) ---		
A	US-A-3 992 330 (M.L. NOAKES et al.) ---		
P,A	EP-A-0 220 468 (INTERATOM GMBH) ---		
A	US-A-4 382 323 (L.R.CHAPMAN) -----		

TECHNICAL FIELDS SEARCHED (Int. Cl.4)

B 01 D 53/34
B 01 D 53/36
B 01 J 35/04
F 01 N 3/10
F 01 N 3/28

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
BERLIN	11-06-1988	CORDERO ALVAREZ M.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document